Contribution of Chemical Constituents to Visibility Reduction During the California Regional PM10/PM2.5 Air Quality Study

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Presented at

CRPAQS Data Analysis Workshop, March 10, 2004

Sacramento, CA

Approach

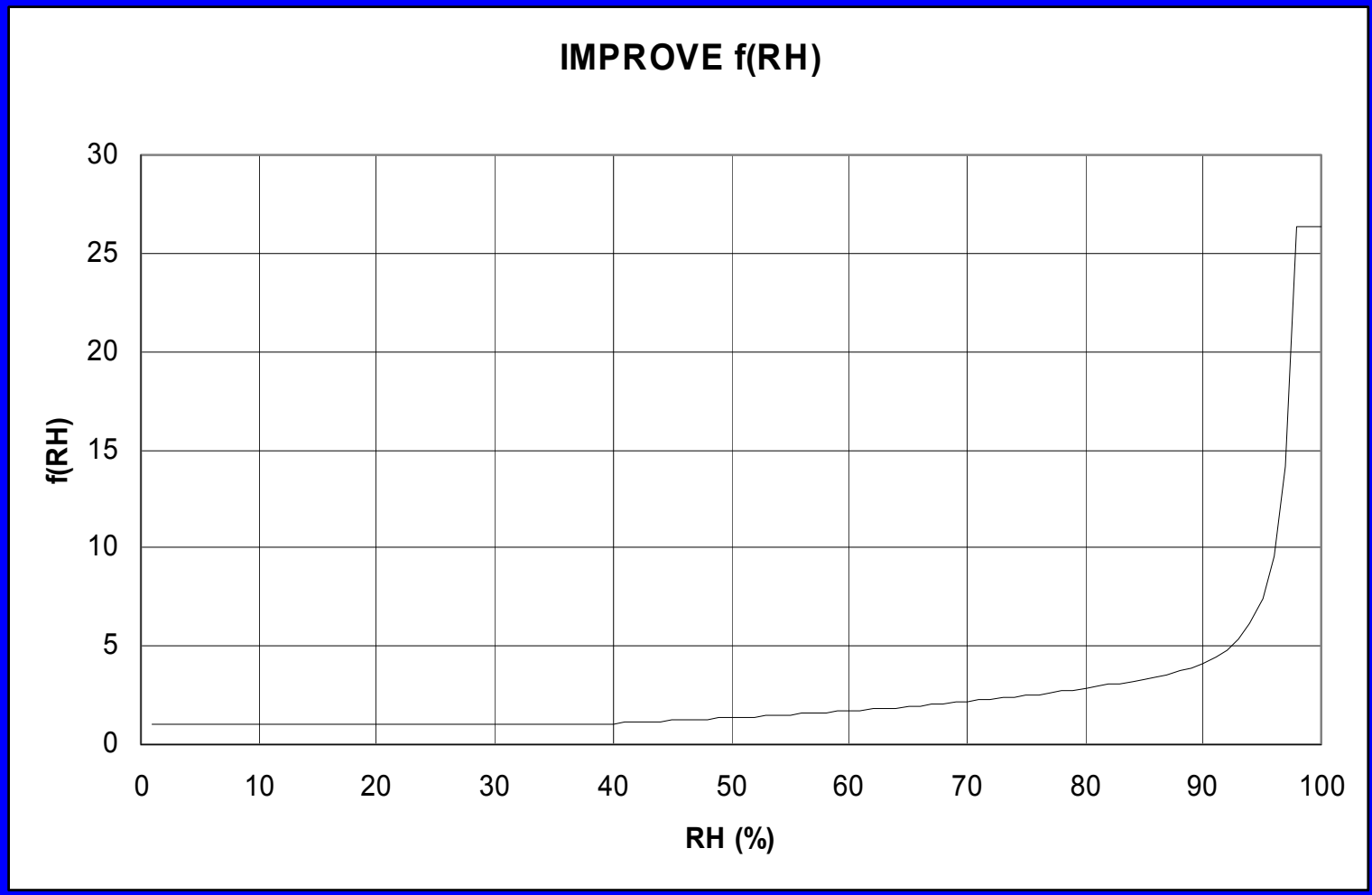
- Applied light extinction efficiencies to 24-hour average particulate matter chemical composition data to estimate constituent contributions to the light extinction coefficient
- Constituents included:
  Fine Soil = 1.89[Al] + 2.14[Si] +1.4[Ca] + 1.43[Fe]
  $NH_4NO_3 = 1.29[NO_3^-]$
  $(NH_4)_2SO_4 = 1.375[SO_4^=]$
  Organic Compounds (OCM) = 1.4[OC]
  Elemental Carbon (EC) = measured EC

Light Extinction Efficiencies

- Used 10 m^2/g for light absorption by EC
- Evaluated light scattering efficiencies developed for IMS95 and for IMPROVE (Interagency Monitoring of Protected Visual Environments) with 24-hour average chemical composition, particle light scattering coefficient (b_{sp}), and relative humidity (RH) data from Fresno First Street (FSF) site
- Chose FSF data because only site with open-air, unheated nephelometer (NGN-2)

IMS95 and IMPROVE Constituent Light Scattering Efficiencies

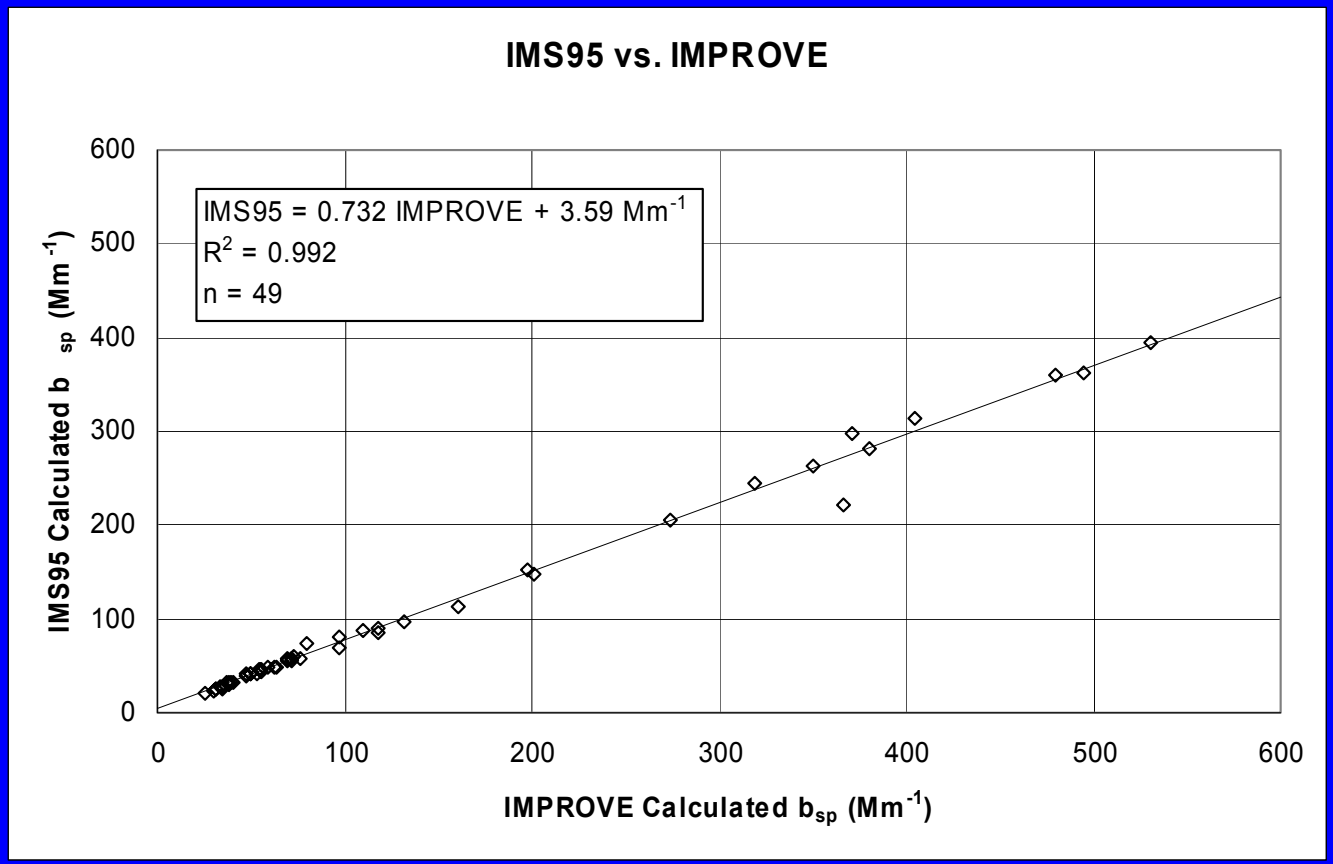
Constituent	IMS95 (m^2/g)	IMPROVE (m^2/g)
Fine Soil	2	1
NH_4NO_3	$2.1/(1\text{-}RH)^{0.7}$	3f(RH)
$(NH_4)_2SO_4$	$2.1/(1\text{-}RH)^{0.7}$	3f(RH)
OC	$2.8/(1\text{-}RH)^{0.2}$	4


IMPROVE f(RH)
f(RH)
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
90
100
RH (%)

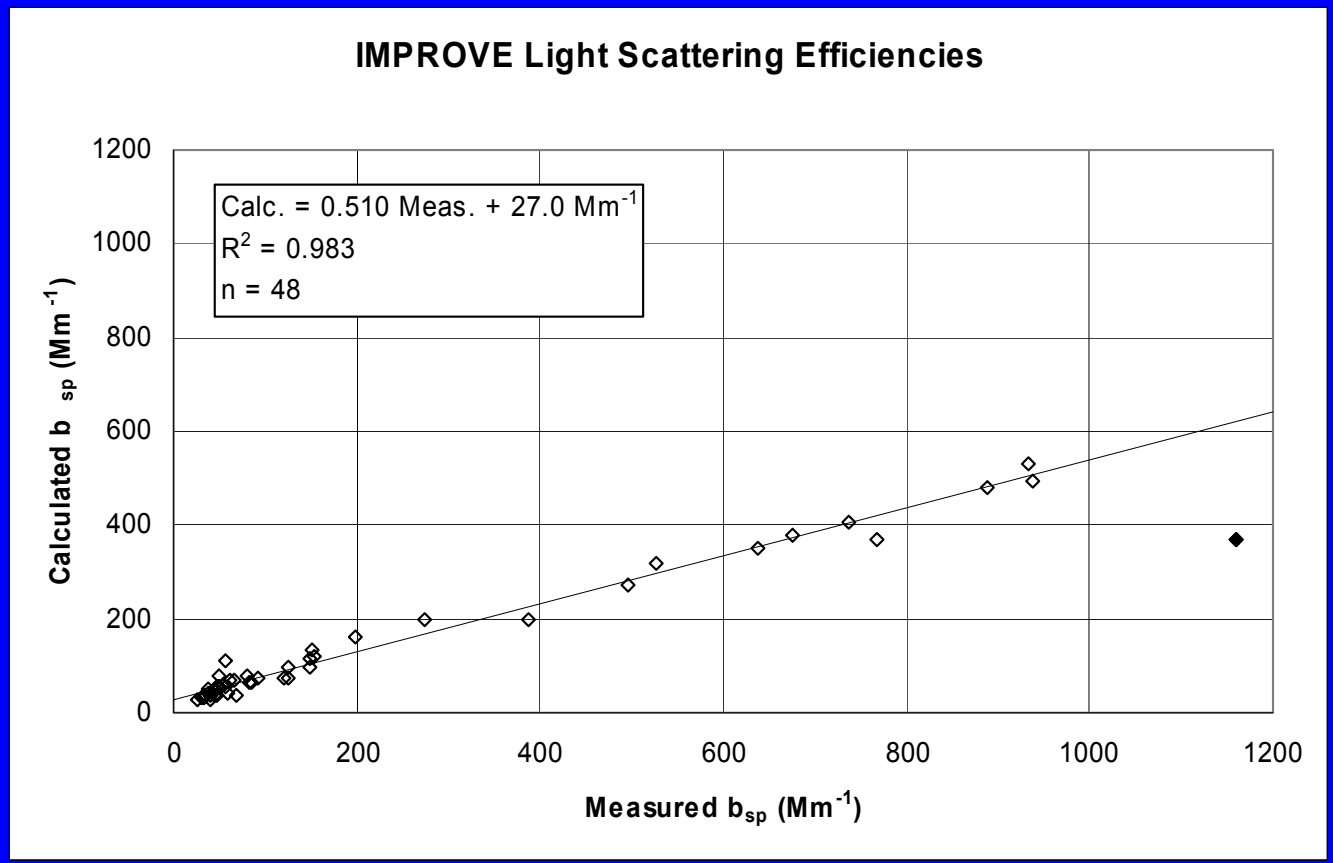
Treatment of Hourly RH and b_{sp}

- Calculated 24-hour average f(RH) and b_{sp}
- Excluded hours with RH above 95% to avoid fog
- Excluded days with less than 18 hours in average

Results with IMS95 and IMPROVE Efficiencies are Well Correlated, but IMS95 is Lower

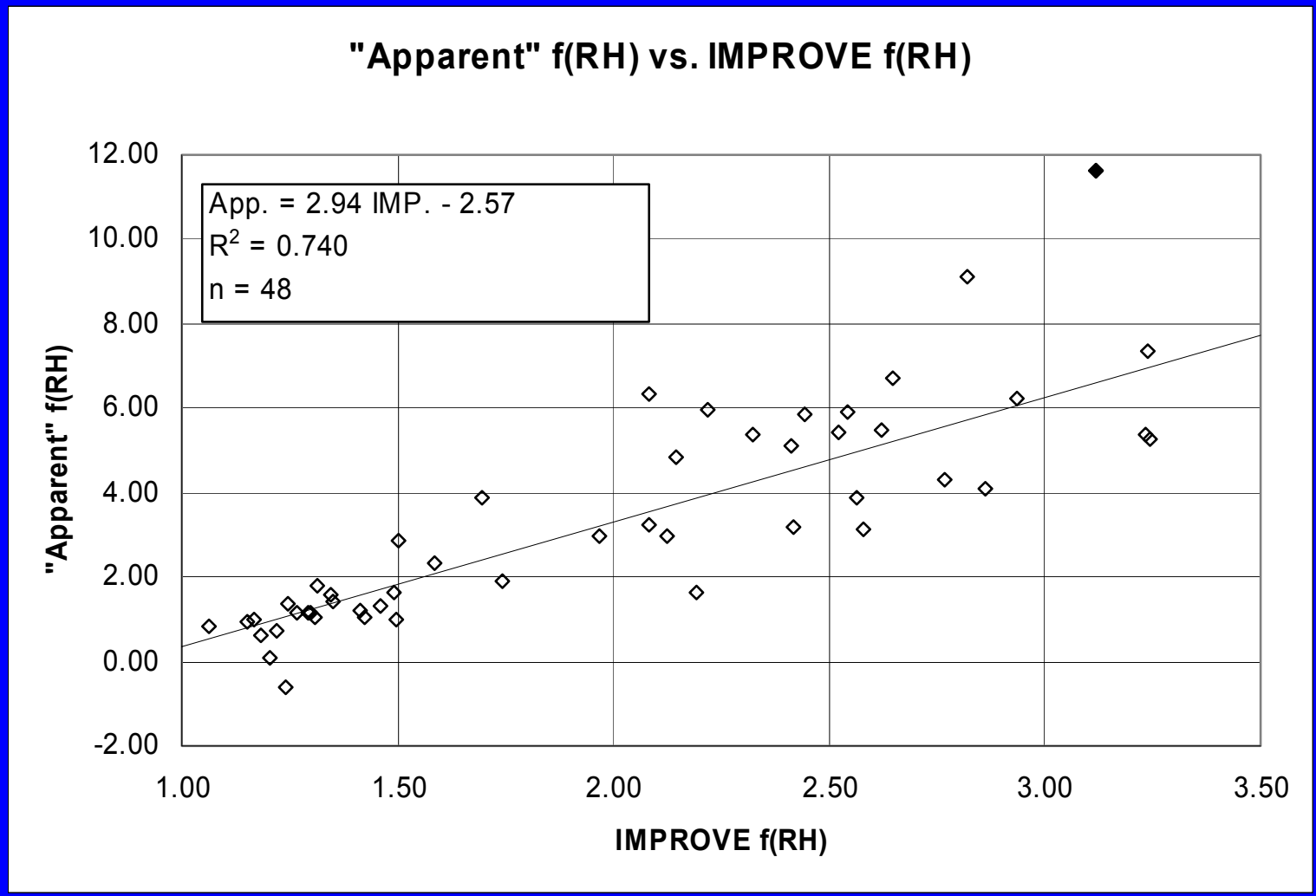


Measured b_{sp} is Under-Predicted

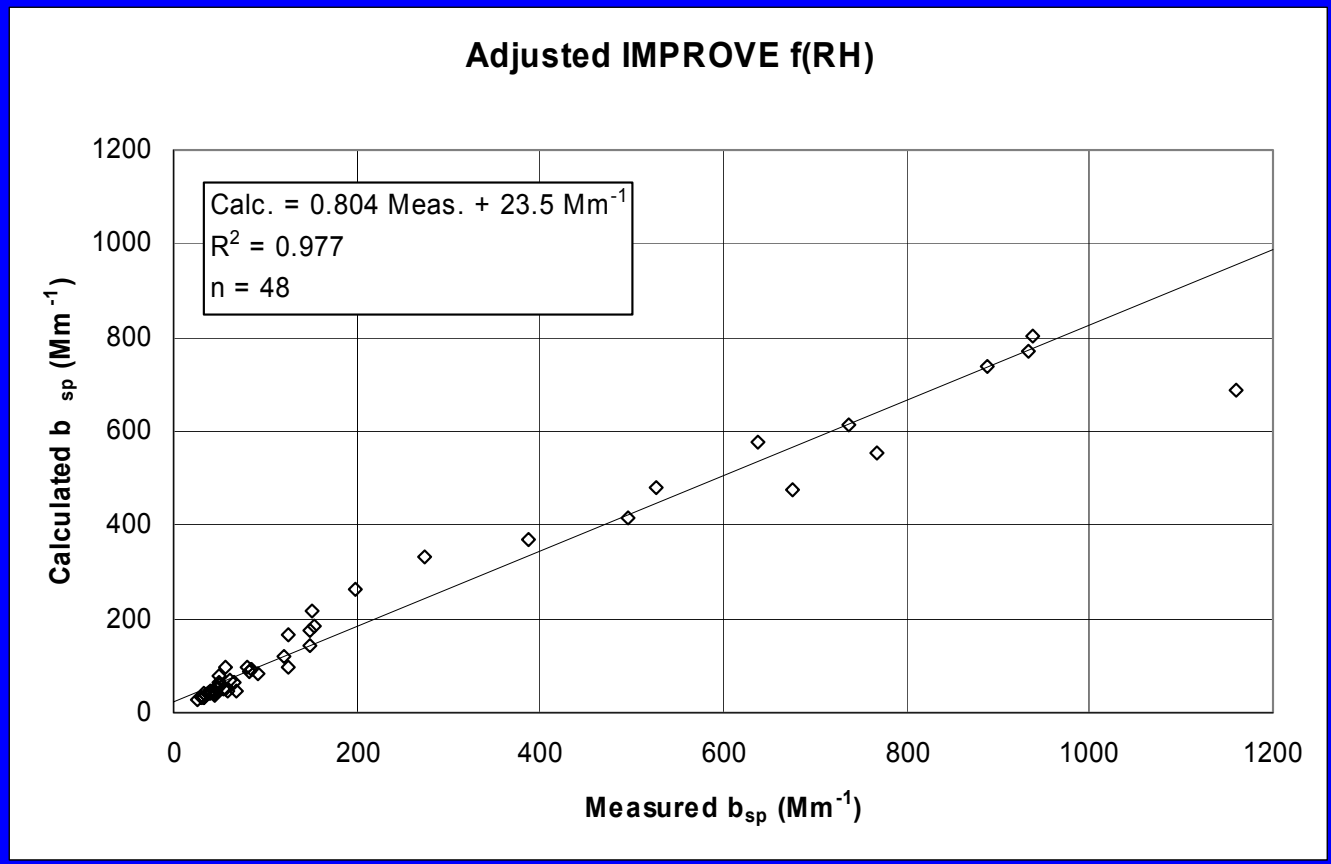


Calculated Adjustment to 24-Hour Average IMPROVE f(RH)

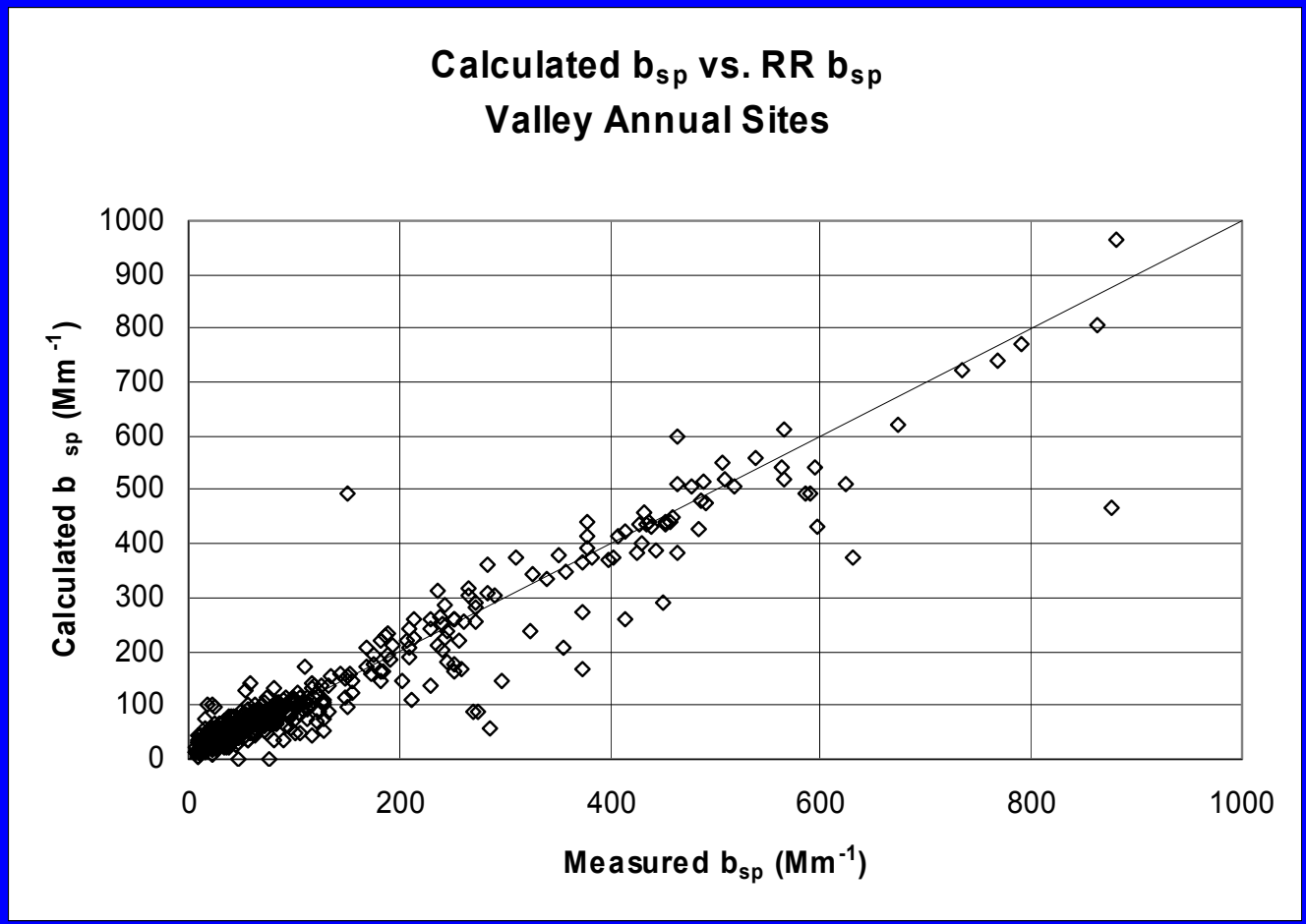
- Calculated "apparent" f(RH) as:
  (measured b_{sp} - soil b_{sp} - OCM b_{sp}) /
  ("dry" NH_4NO_3 b_{sp} + "dry" $(NH_4)_2SO_4$ b_{sp})
- Used results from linear regression of "apparent" 24-hour average f(RH) vs. 24-hour average IMPROVE f(RH)


"Apparent" f(RH) vs. IMPROVE f(RH)
App. = 2.94 IMP. - 2.57
R2 = 0.740
n = 48
"Apparent" f(RH)
IMPROVE f(RH)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
1.00
1.50
2.00
2.50
3.00
3.50

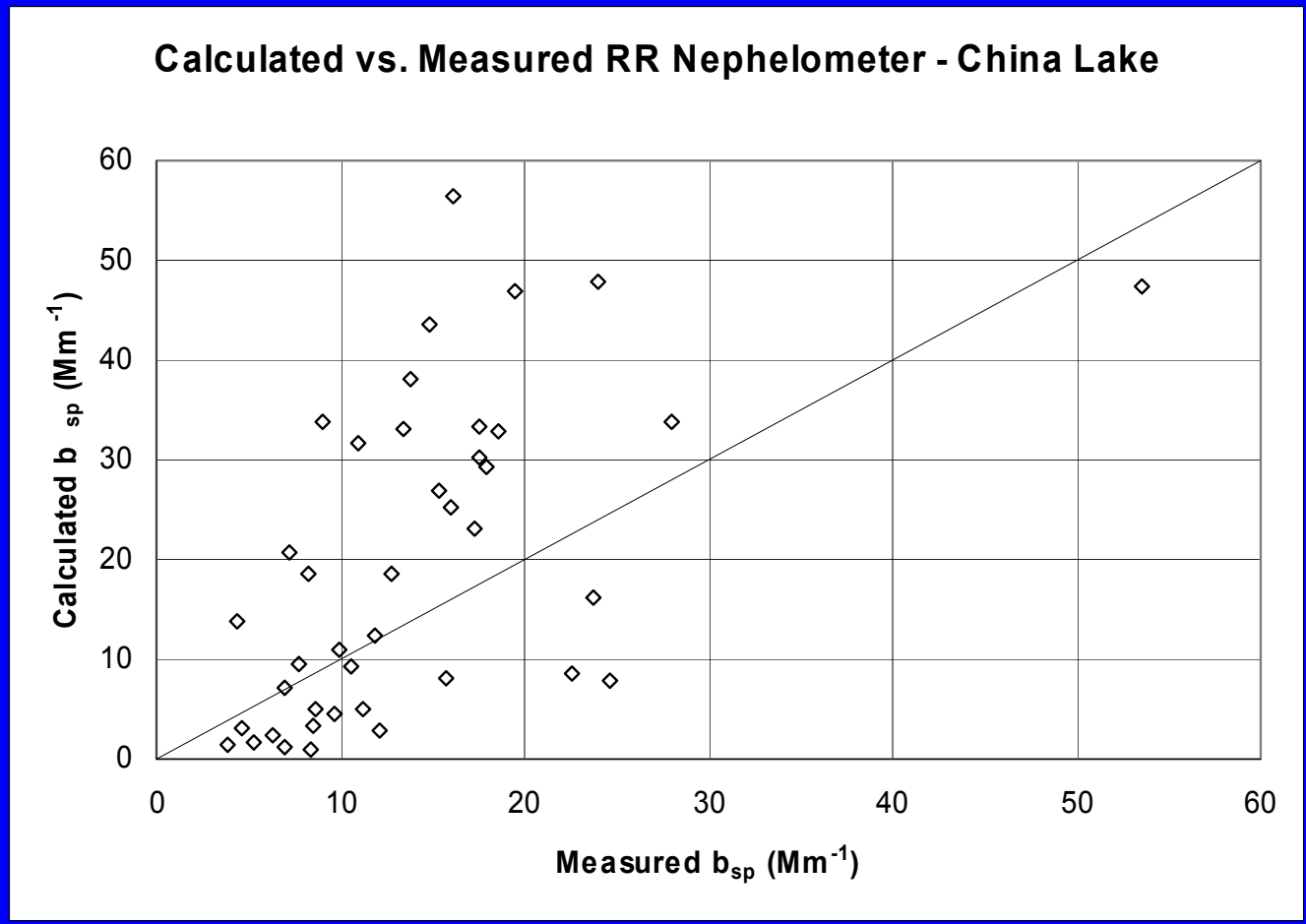
Adjustment Improves Agreement



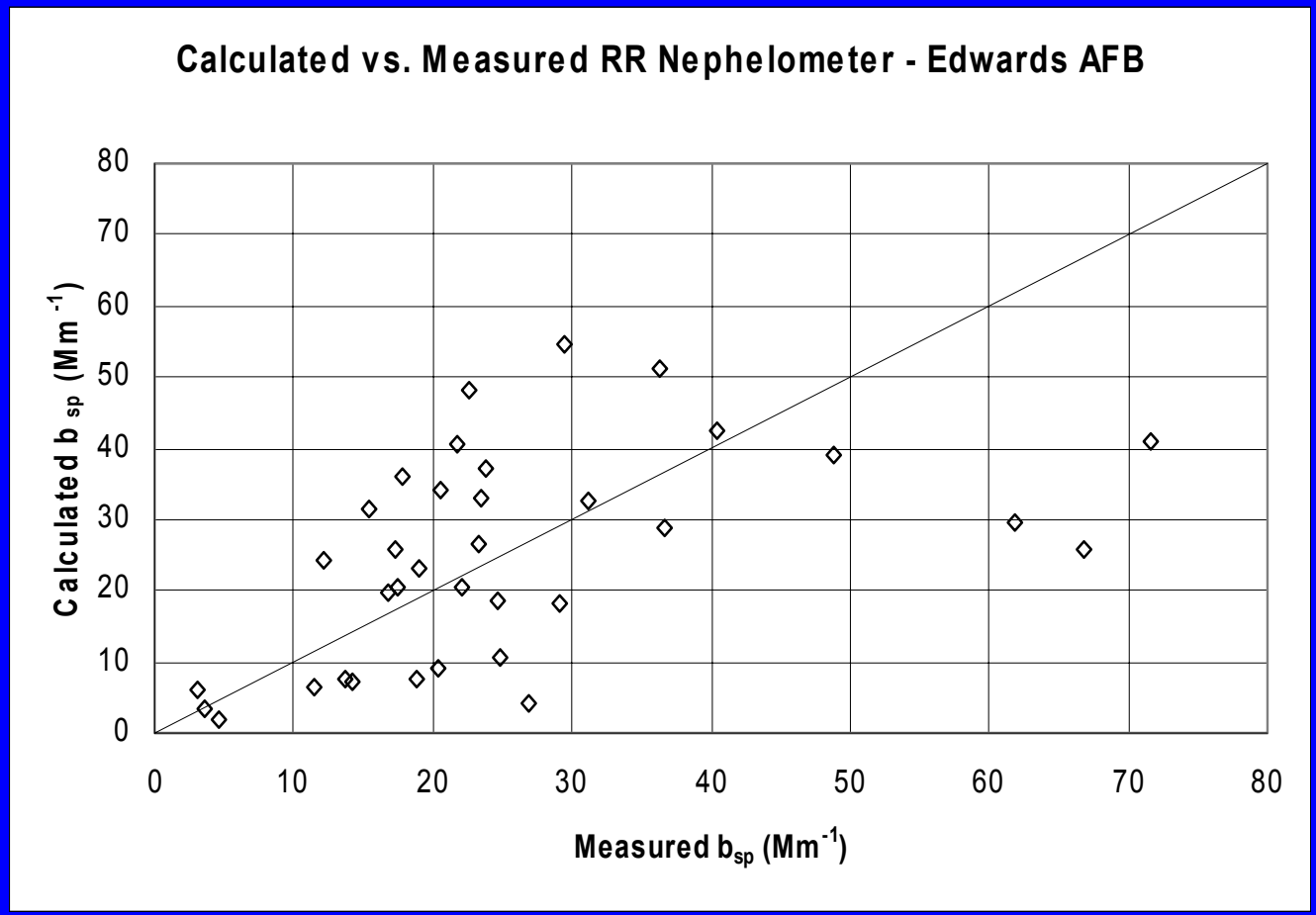
Comparison of Calculated b_{sp} with Radiance Research (RR) Neph. Measurements



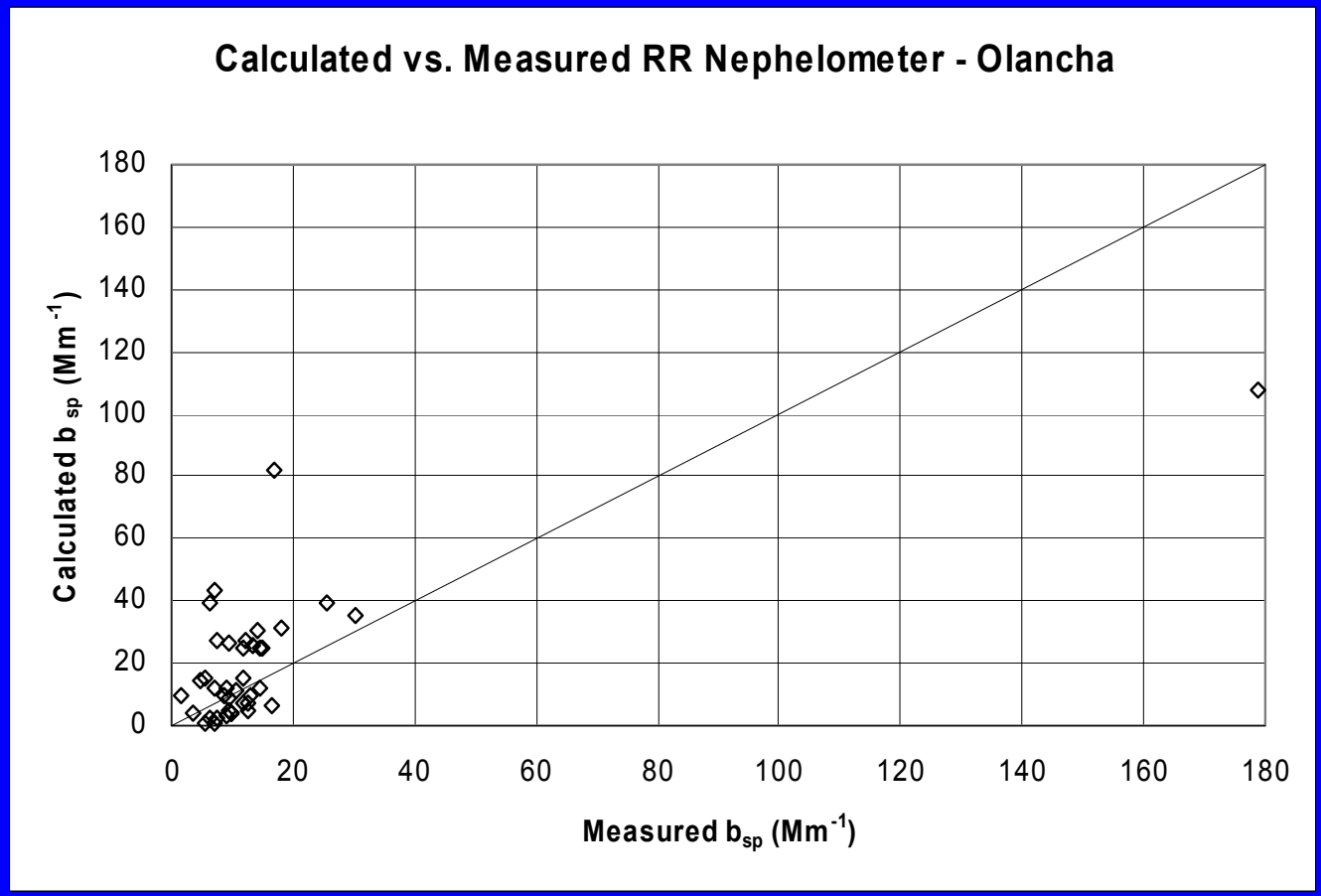
Agreement is Poor at Mojave Desert Sites



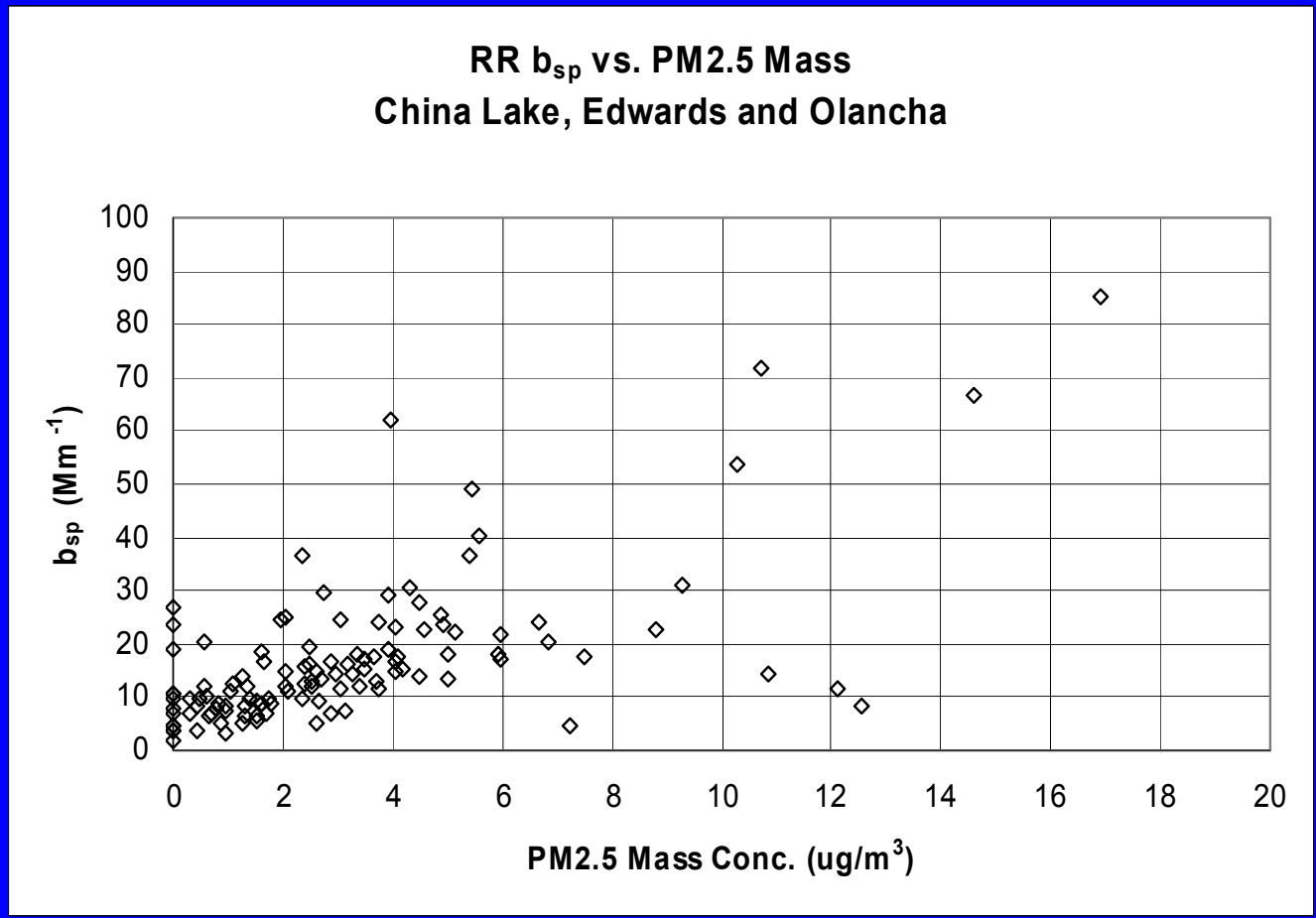
Agreement is Poor at Mojave Desert Sites



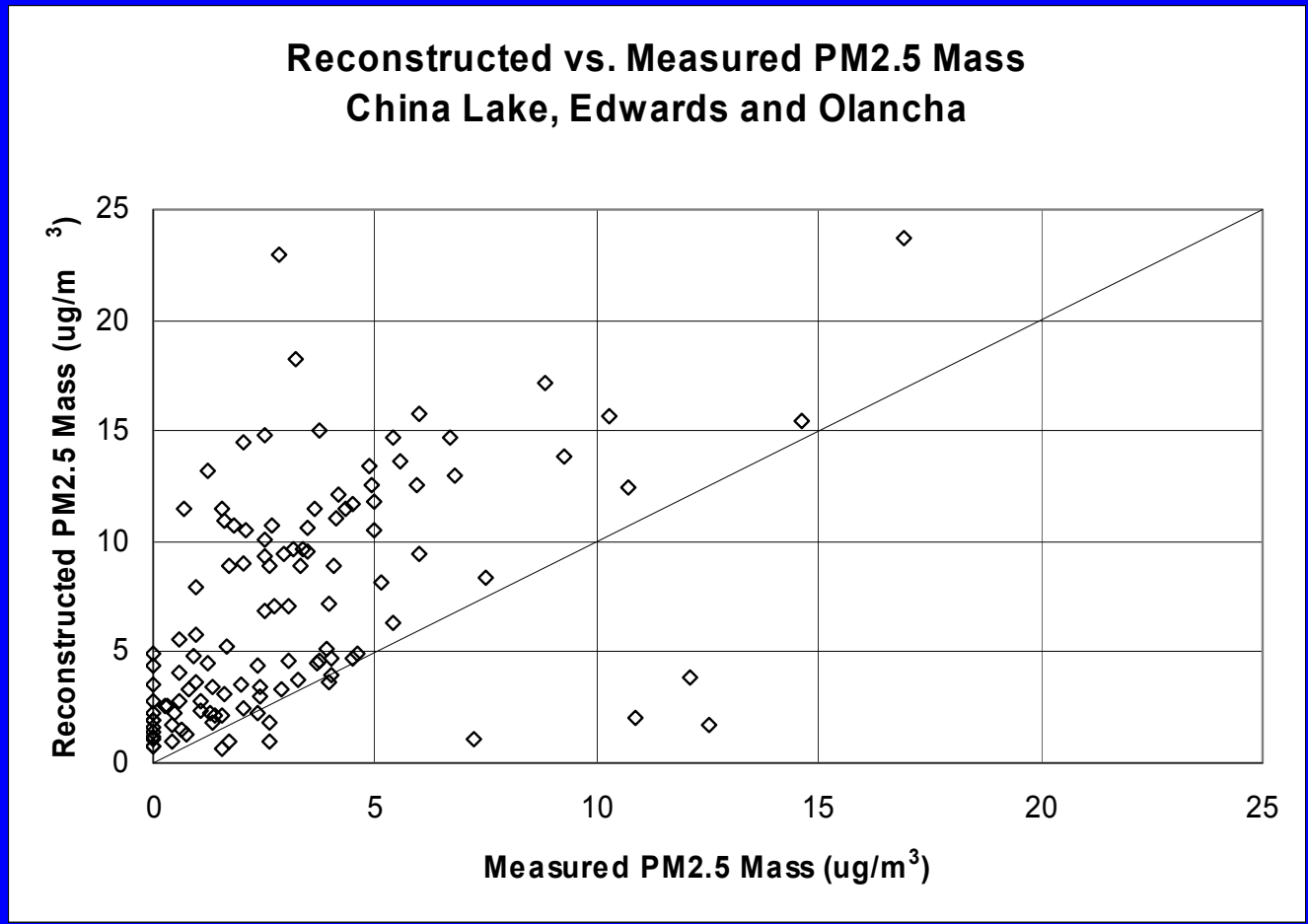
Agreement is Poor at Mojave Desert Sites



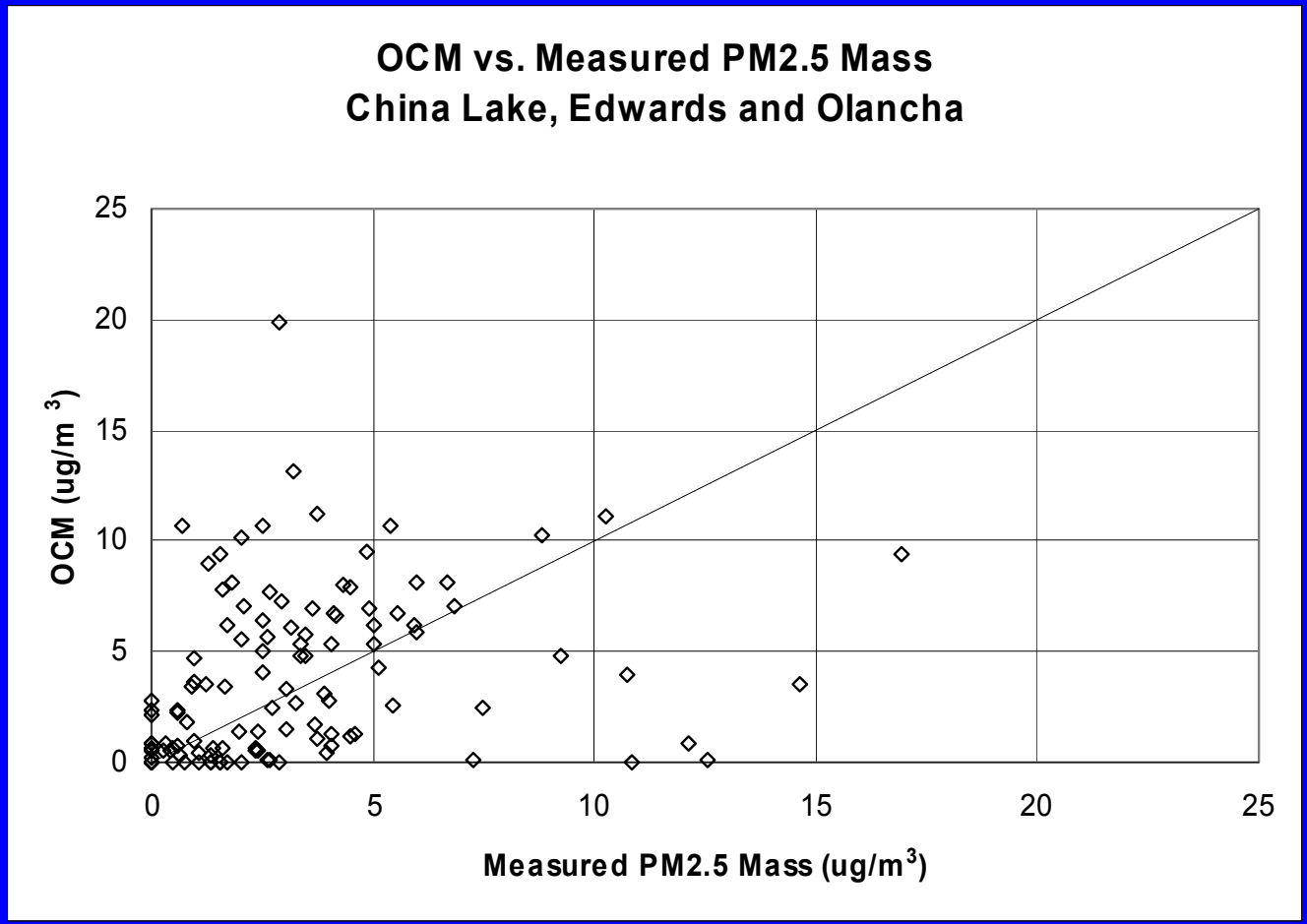
Measured b_{sp} is Moderately Correlated with PM2.5 Mass at Desert Sites



Reconstructed Mass is Higher than Measured Mass at Desert Sites

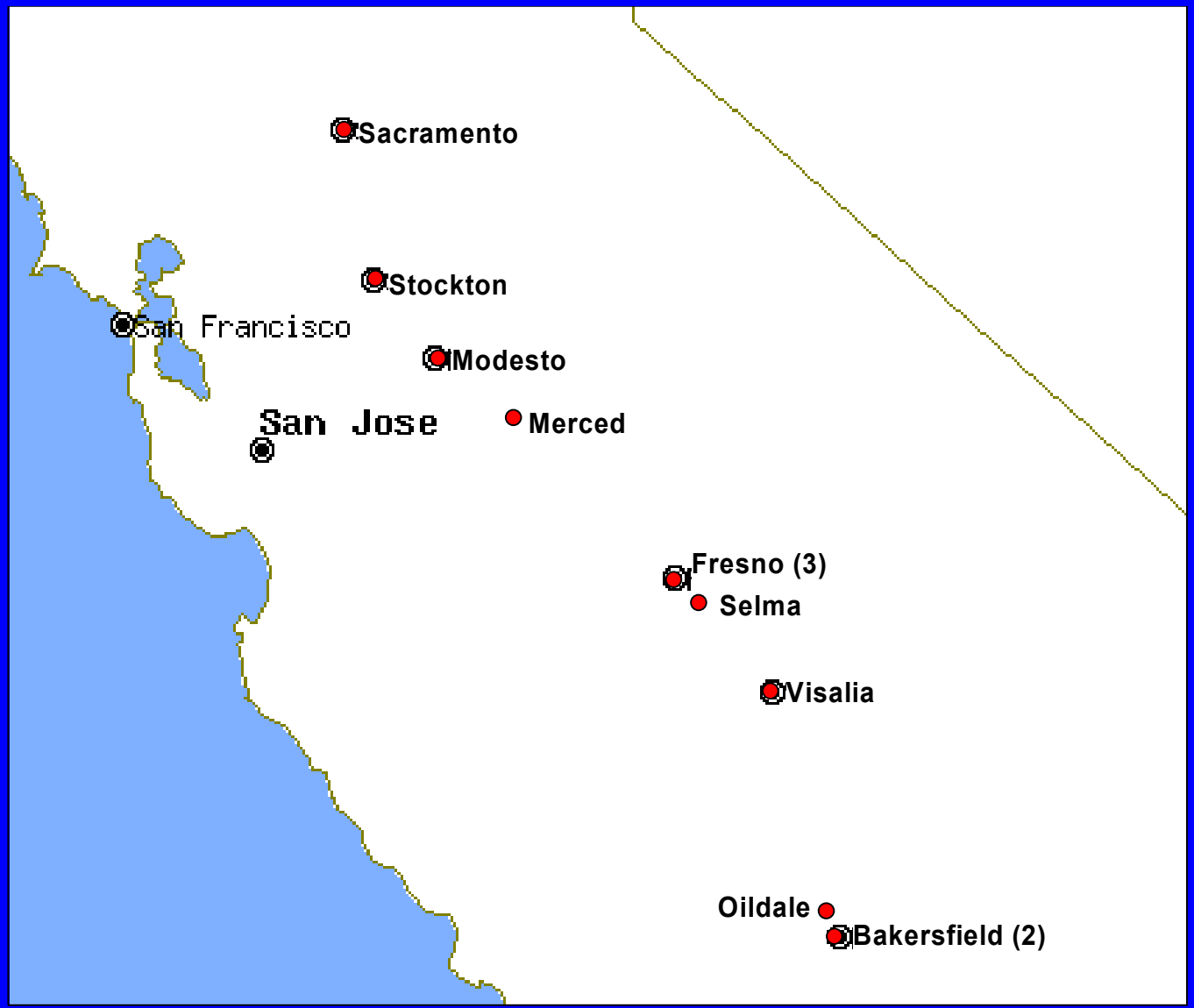


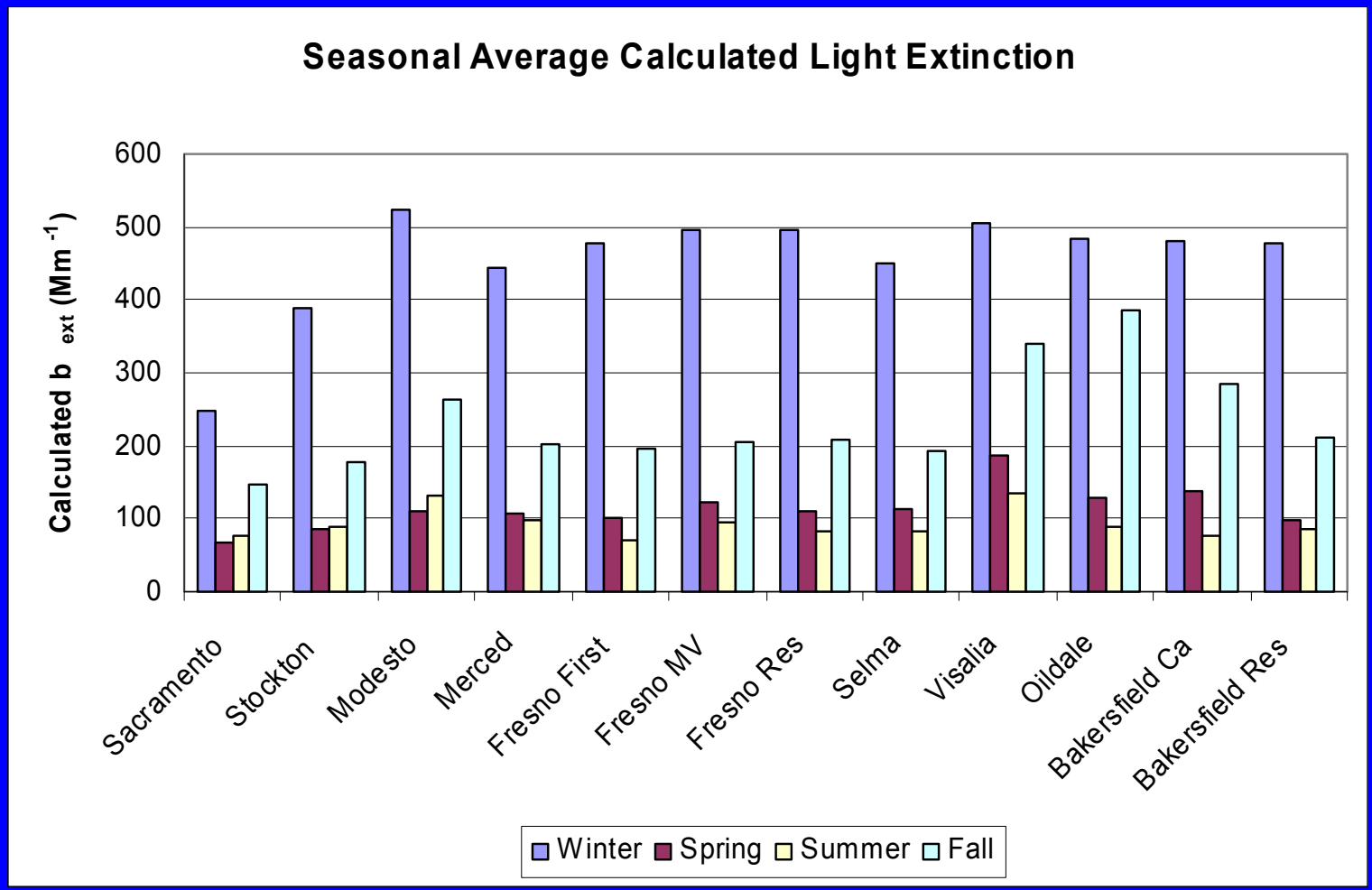
Calculated Organic Compound Mass (OCM) is Frequently Higher than Measured PM2.5 Mass at Desert Sites

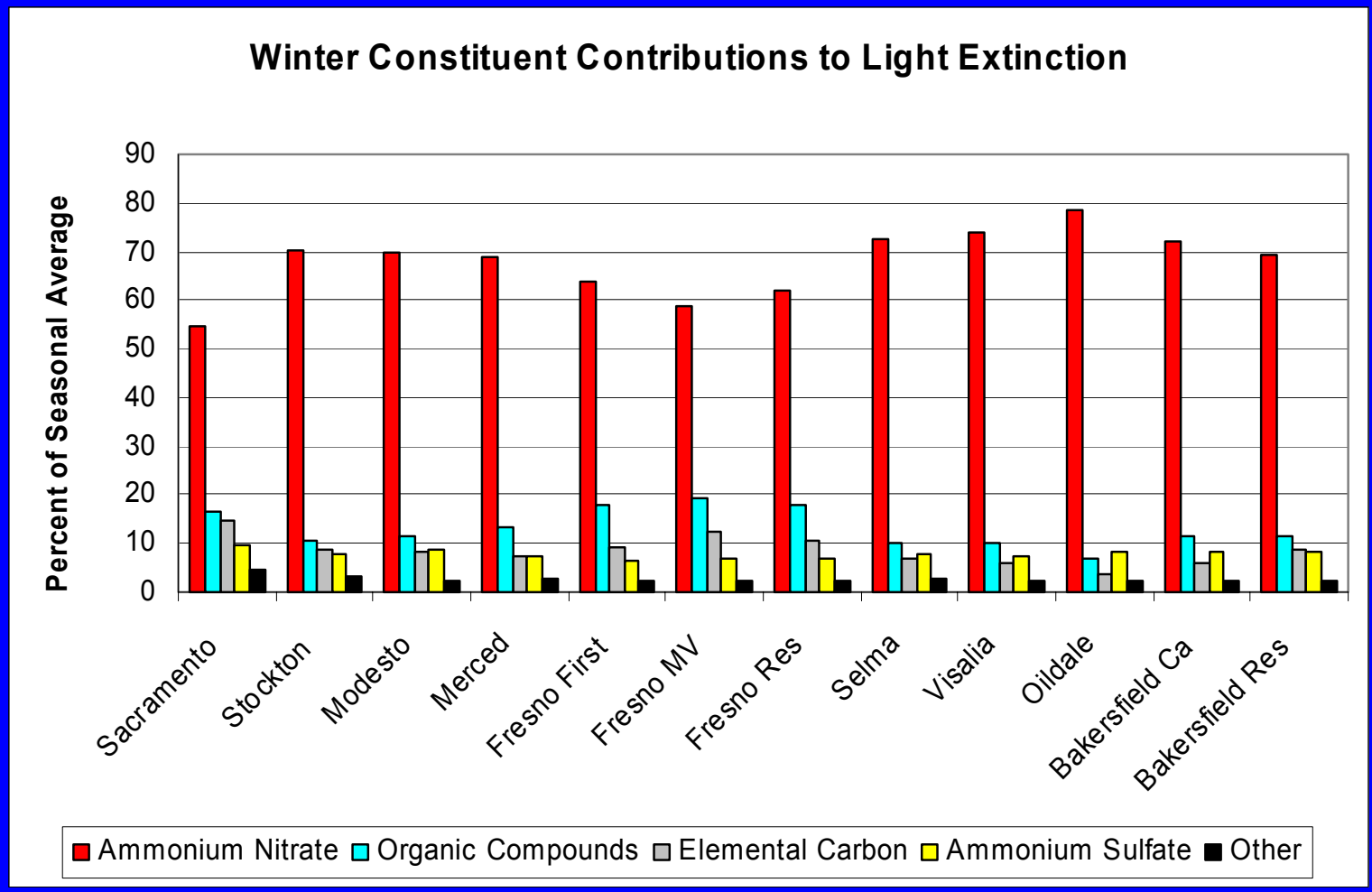


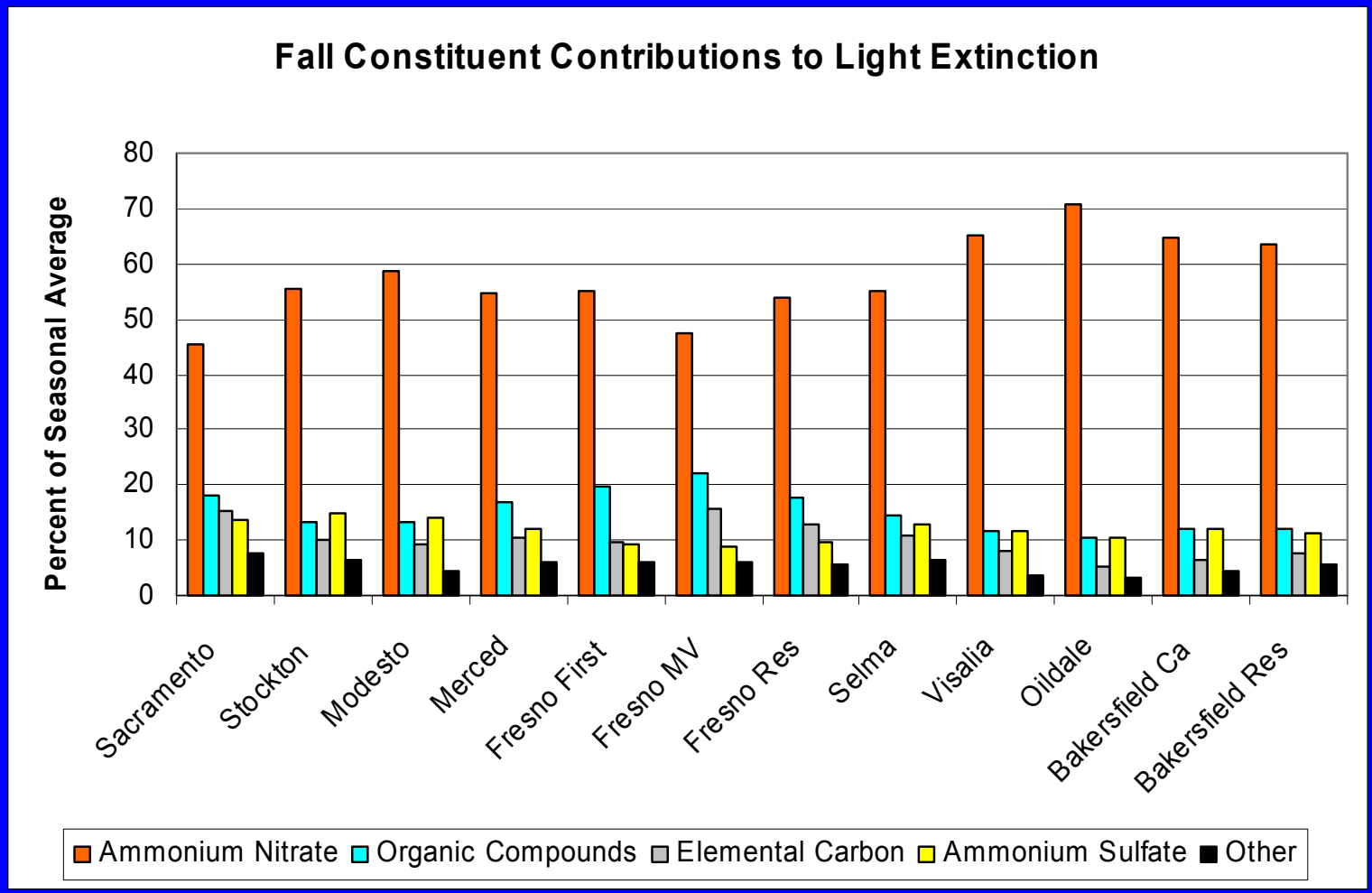
Application of Light Extinction Efficiencies to SJV Sites

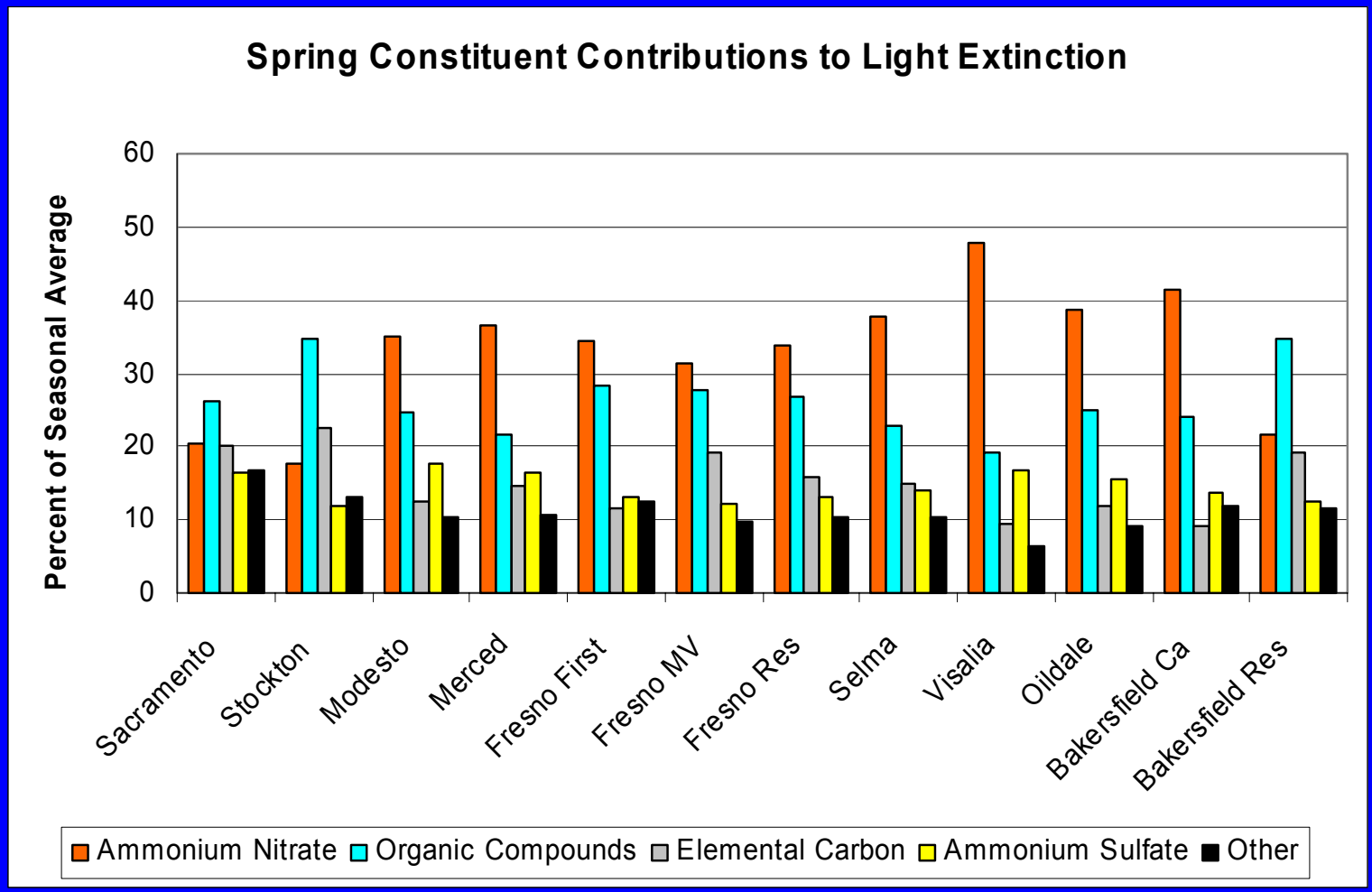
- Applied to 11 sites with annual relative humidity and PM2.5 chemical composition data
- Data available from 12/99 - 1/01
- Calculated f(RH) for every hour and averaged over 24-hour filter sampling periods
- Excluded hours with RH above 95% to avoid fog

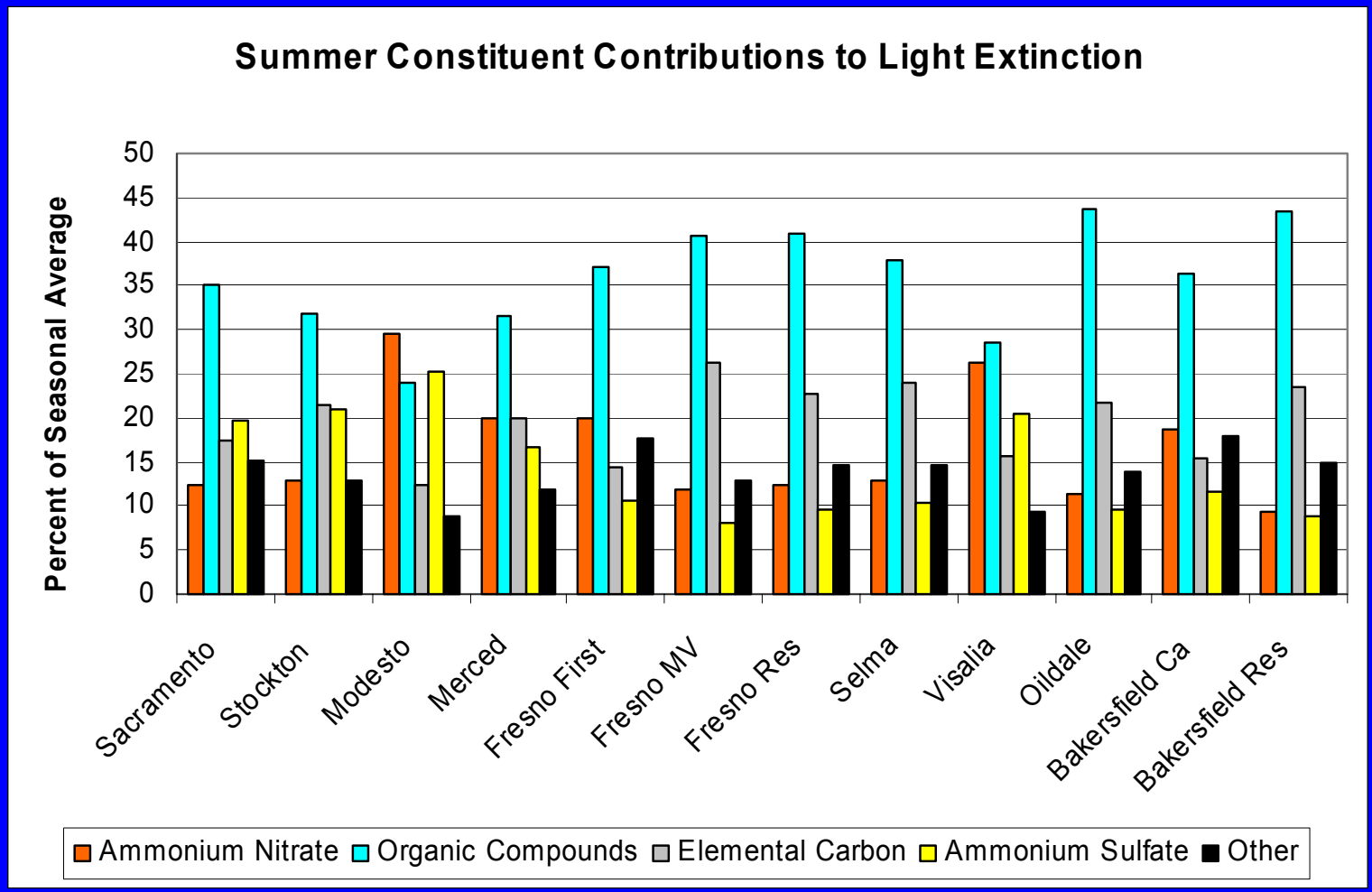

Sacramento
Stockton
San Francisco
Modesto
San Jose
Merced
Fresno (3)
Selma
Visalia
Oildale
Bakersfield (2)

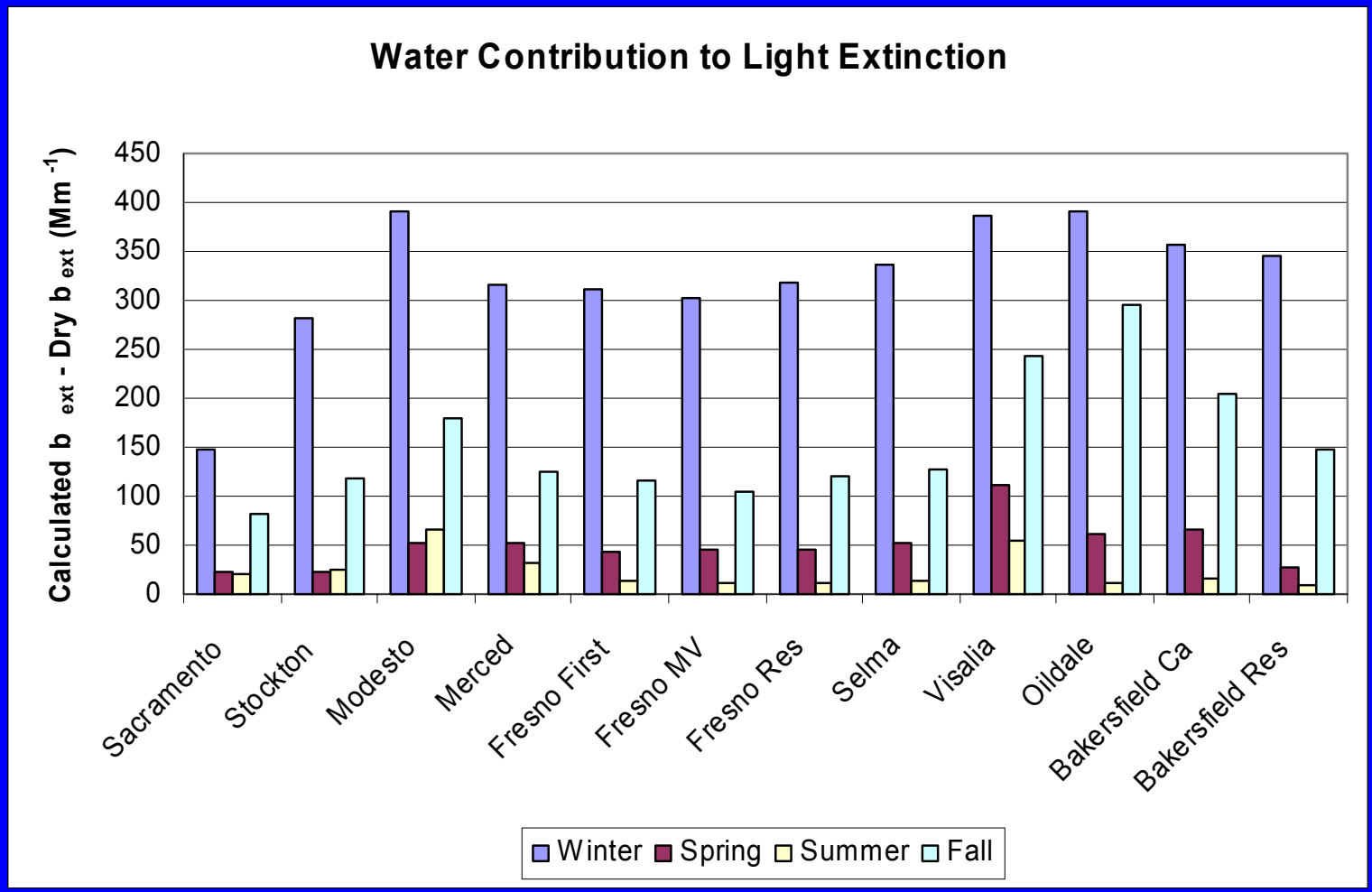

Seasonal Average Calculated Light Extinction
Calculated b ext (Mm -1)
600
500
400
300
200
100
0
Sacramento
Stockton
Modesto
Merced
Fresno First
Fresno MV
Fresno Res
Selma
Visalia
Oildale
Bakersfield Ca
Bakersfield Res
Winter
Spring
Summer
Fall

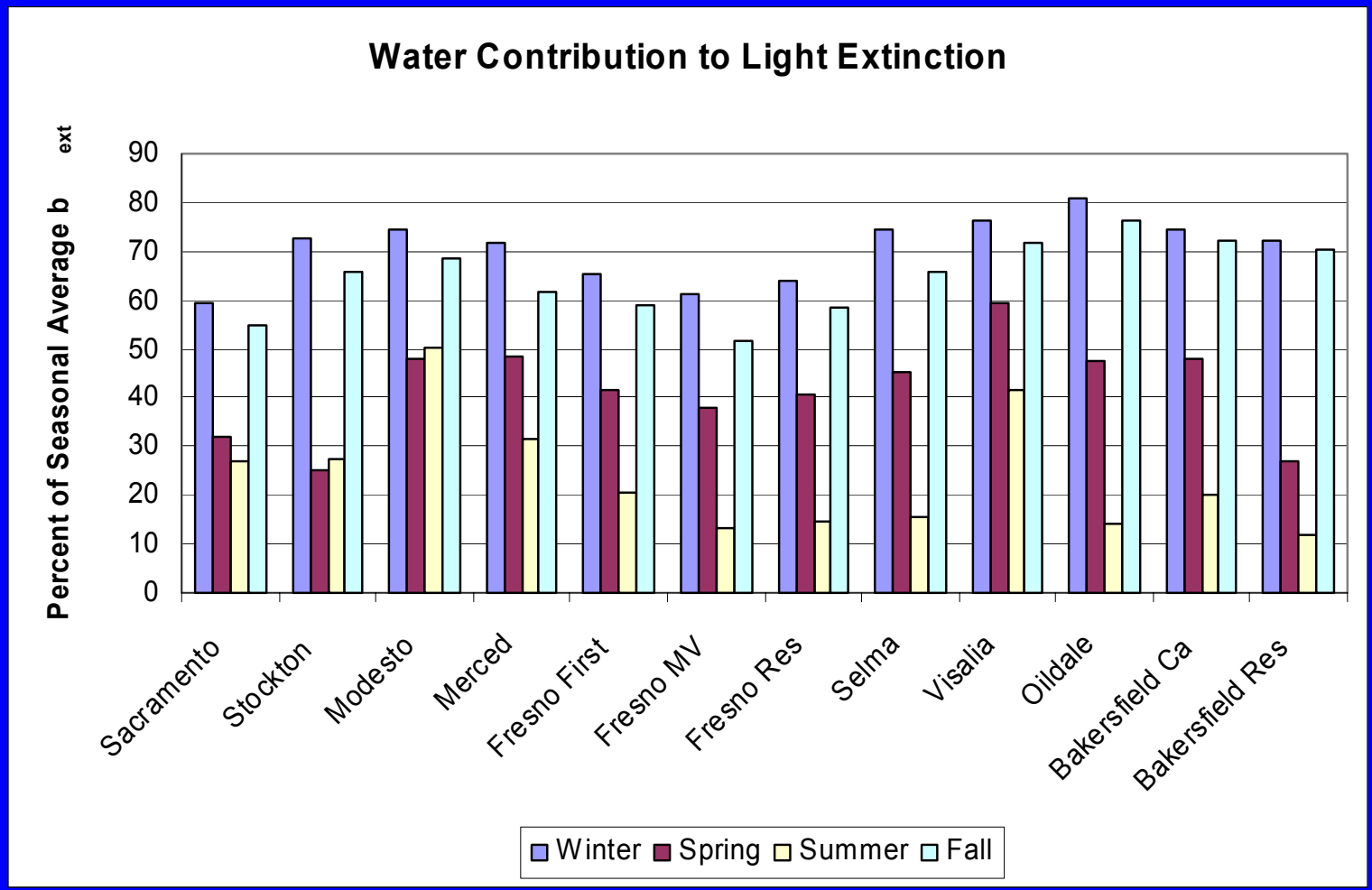

Winter Constituent Contributions to Light Extinction
Percent of Seasonal Average
90
80
70
60
50
40
30
20
10
0
Sacramento
Stockton
Modesto
Merced
Fresno First
Fresno MV
Fresno Res
Selma
Visalia
Oildale
Bakersfield Ca
Bakersfield Res
Ammonium Nitrate
Organic Compounds
Elemental Carbon
Ammonium Sulfate
Other


Fall Constituent Contributions to Light Extinction
Percent of Seasonal Average
80
70
60
50
40
30
20
10
0
Sacramento
Stockton
Modesto
Merced
Fresno First
Fresno MV
Fresno Res
Selma
Visalia
Oildale
Bakersfield Ca
Bakersfield Res
Ammonium Nitrate
Organic Compounds
Elemental Carbon
Ammonium Sulfate
Other


Spring Constituent Contributions to Light Extinction
Percent of Seasonal Average
60
50
40
30
20
10
0
Sacramento
Stockton
Modesto
Merced
Fresno First
Fresno MV
Fresno Res
Selma
Visalia
Oildale
Bakersfield Ca
Bakersfield Res
Ammonium Nitrate
Organic Compounds
Elemental Carbon
Ammonium Sulfate
Other


Summer Constituent Contributions to Light Extinction
Percent of Seasonal Average
50
45
40
35
30
25
20
15
10
5
0
Sacramento
Stockton
Modesto
Merced
Fresno First
Fresno MV
Fresno Res
Selma
Visalia
Oildale
Bakersfield Ca
Bakersfield Res
Ammonium Nitrate
Organic Compounds
Elemental Carbon
Ammonium Sulfate
Other


Water Contribution to Light Extinction
Calculated b ext - Dry b ext (Mm -1)
450
400
350
300
250
200
150
100
50
0
Sacramento
Stockton
Modesto
Merced
Fresno First
Fresno MV
Fresno Res
Selma
Visalia
Oildale
Bakersfield Ca
Bakersfield Res
Winter
Spring
Summer
Fall


Water Contribution to Light Extinction
Percent of Seasonal Average b ext
90
80
70
60
50
40
30
20
10
0
Sacramento
Stockton
Modesto
Merced
Fresno First
Fresno MV
Fresno Res
Selma
Visalia
Oildale
Bakersfield Ca
Bakersfield Res
Winter
Spring
Summer
Fall

Summary

- Previously developed light scattering efficiencies under-predicted measured light scattering, but adjustment to f(RH) improved agreement
- Calculated light scattering agrees reasonably well with RR measurements at SJV sites
- Agreement is poor at Mojave Desert sites
- Calculated total light extinction is highest during winter and lowest during summer
- NH_4NO_3 is the largest contributor at all sites during winter and fall and at several sites during spring
- Organic compounds are the highest contributor at most sites during summer

Summary (continued)

- Water associated with ammonium nitrate and ammonium sulfate accounts for about 60% to 80% of calculated light extinction during winter and about 50% to 75% during fall